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RECOGNISING ACHIEVEMENT

GCE

# Physics B (Advancing Physics)

Advanced GCE

Unit **G494:** Rise and Fall of the Clockwork Universe

# Mark Scheme for June 2012

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All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

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Annotations in scoris

| Annotation | Meaning |
|---|---|
|  | Benefit of doubt given |
|  | Contradiction |
|  | Incorrect response |
|  | Error carried forward |
|  | Follow through |
|  | Not answered question |
|  | Benefit of doubt not given |
|  | Power of 10 error |
|  | Omission mark |
|  | Rounding error |
|  | Error in number of significant figures |
|  | Correct response |
|  | Arithmetic error |
|  | Wrong physics or equation |

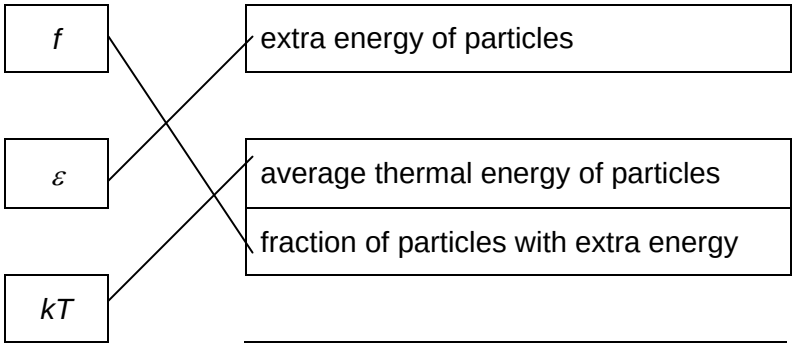
Annotations in Mark Scheme

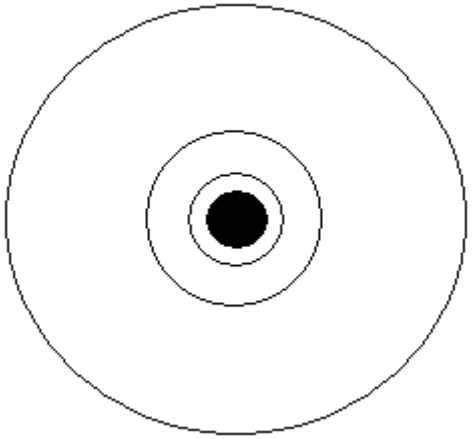
| Annotation | Meaning |
|---|---|
| **/** | alternative and acceptable answers for the same marking point |
| **(1)** | Separates marking points |
| **reject** | Answers which are not worthy of credit |
| **not** | Answers which are not worthy of credit |
| **IGNORE** | Statements which are irrelevant |
| **ALLOW** | Answers that can be accepted |
| **( )** | Words which are not essential to gain credit |
| **__** | Underlined words must be present in answer to score a mark |
| **ecf** | Error carried forward |
| **AW** | Alternative wording |
| **ORA** | Or reverse argument |

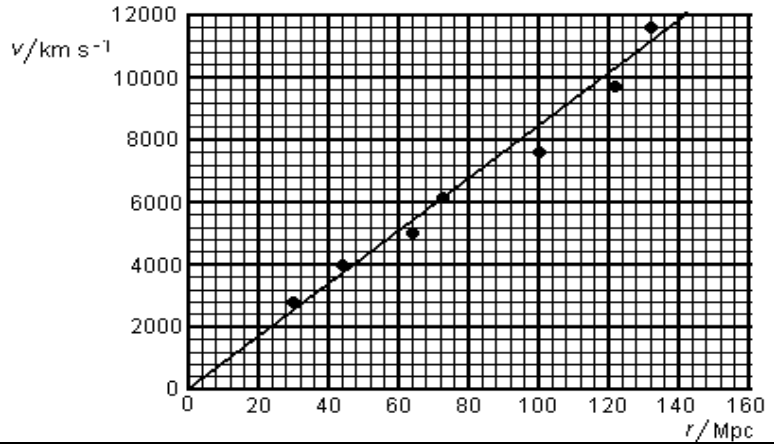
**Subject Specific Marking Instructions**

The following questions should be annotated with ticks to show where marks have been awarded in the body of the text:

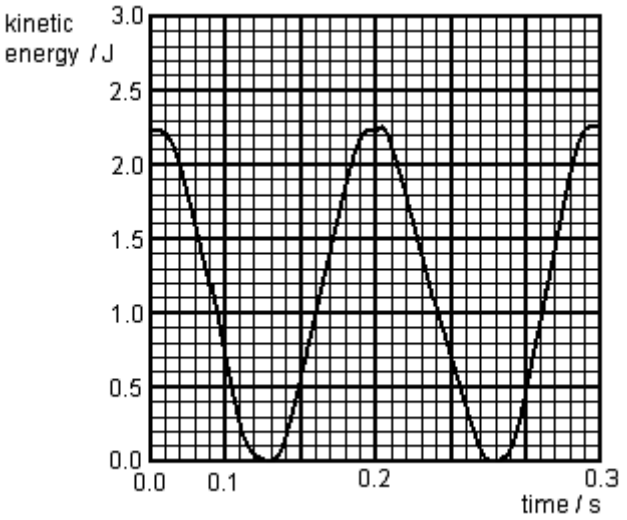
<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>1</td><td>(a)</td><td></td><td>J kg$^{-1}$</td><td>1</td><td></td></tr>
<tr><td></td><td>(b)</td><td></td><td>N s</td><td>1</td><td></td></tr>
<tr><td>2</td><td>(a)</td><td></td><td>1.8(23)$\times 10^4$ J</td><td>1</td><td></td></tr>
<tr><td></td><td>(b)</td><td></td><td>B</td><td>1</td><td></td></tr>
<tr><td>3</td><td></td><td></td><td>$\gamma = \frac{1}{\sqrt{1-\left(\frac{2.8\times10^8}{3.0\times10^8}\right)^2}} = 2.79$ ;<br>half-life = 2.79 $\times$ 10 = 27.9 or 28 $\mu$s</td><td>2</td><td>evaluation of $\gamma$;<br><br><br>ecf incorrect calculated value of $\gamma$ from correct substitution into formula</td></tr>
<tr><td>4</td><td>(a)</td><td></td><td>Probability of decay of a nucleus per unit time. ✓</td><td>1</td><td></td></tr>
<tr><td></td><td>(b)</td><td></td><td><table><tr><th>t / s</th><th>N</th><th>$\Delta N$</th></tr><tr><td>0</td><td>100</td><td>-21</td></tr><tr><td>10</td><td>79</td><td>-17</td></tr><tr><td>20</td><td>62</td><td>-13</td></tr><tr><td>30</td><td>49</td><td></td></tr></table></td><td>2</td><td>79 correct for (1)<br>accept 79.0<br>all rest completely correct for (1)<br>only accept whole numbers of nucleii for the rest<br>no ecf on incorrect first value (79)<br>ignore contents of bottom r.h. cell</td></tr>
<tr><td></td><td>(c)</td><td></td><td>Use a smaller time interval / more steps in same time</td><td>1</td><td>not just more steps</td></tr>
</table>

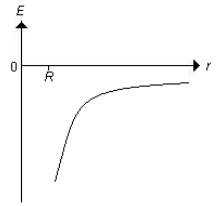
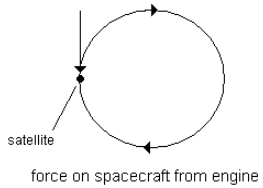
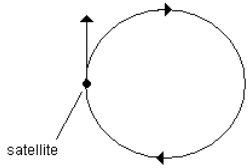
| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 5 | (a) | | change of KE = 0.5 ×1.8 ($2.9^2$ - $0.52^2$) = 7.3(3) J | 1 | look for correct method as well as correct answer to at least 1 d.p. |
| | (b) | | change of GPE = 1.8 × 9.8 × (0.73 - 0.11) = 10.9 / 11 J;<br>work done = 10.9 - 7.3 = 3.6 J; | 2 | no ecf from incorrect GPE change<br>KE change = 7.0 J gives 3.9 / 4(.0) J for (2)<br>**not** -3.6 J |
| 6 | | | EITHER<br>initial $p$ = 1200 × 2.3 - 830 × 3.7 = -3.1×$10^2$ Ns;<br>OR<br>1200 × 2.3 - 830 × 3.7 = (1200 + 830) × $v$;<br>THEN<br>final velocity = -3.1×$10^2$ / 2030 = -0.15(3) m $s^{-1}$; | 3 | calculation of initial momentum (1)<br>calculation of final speed for (1)<br>no ecf from incorrect initial $p$<br>negative final velocity (1)<br><br>**accept** to the left instead of - |
| 7 | | |  | 1 | |

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 8 | | |  | 1 | Three circles centred on the star, with middle circle clearly closer to the inner one than the outer one.<br><br>Accept freehand circles.<br><br>**ignore** written comments |
| 9 | (a) | | B (total energy) | 1 | |
| | (b) | | C (acceleration) | 1 | |
| | | | **Total** | **20** | |

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| **10** | (a) | (i) | *r* is distance, *v* is velocity / speed;<br>of a galaxy (relative to Earth); | 2 | **not** *r* is radius<br>**not** galaxy and anything else |
| | | (ii) | $(H_0 = \frac{v}{r}) = \frac{\text{ms}^{-1}}{\text{m}} = \text{s}^{-1}$ | 1 | **accept** m $s^{-1}$ = $H_0$ × m etc. |
| | (b) | | best straight line through origin (1);<br>THEN<br>data points from line;<br>conversion to SI units;<br>calculation of $H_0 = 2.7\times10^{-18}$ $s^{-1}$;<br><br>**look for** from $2.4\times10^{-18}$ to $2.9\times10^{-18}$ $s^{-1}$ for (3).<br>must have some working for $2.4\times10^{-18}$<br><br>**look for** from $2.4\times10^{-21}$ to $2.9\times10^{-21}$ $s^{-1}$ for (2)<br><br>**look for** from $7.5\times10^{4}$ to $8.8\times10^{4}$ $s^{-1}$ for (2)<br><br>**look for** from 75 to 88 $s^{-1}$ for (1) | 4 | not freehand<br>look for line whose gradient lies within limits of overlay<br>  |
| | (c) | (i) | (Hubble Law) suggests galaxies are moving apart (from each other) / space is expanding;<br>so must have been in the same place at an earlier time (Big Bang); | 2 | **accept** universe for space, stars / planets for galaxies<br>**not just** speed of recession increases with distance |
| | | (ii) | (a galaxy which has a constant velocity *v*) and moves a distance *r* since Big Bang in a time *t,* then $t = r/v = 1/H_0$; | 1 | look for complete answer to award the mark<br>**not just** $t = r/v$ combined with $v = H_0 r$ |
| | | (iii) | $1.3(2)\times10^{10}$ yr | 1 | |
| | | | **Total** | **11** | |

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| **11** | (a) | (i) | $T$ = 15 + 273 = 288 K;<br>$N = pV/kT = 5.7(0)\times10^{24}$; | 2 | ecf any incorrect $T$: e.g. $T$ = 15 K gives $1.09\times10^{26}$ for (1) |
| | | (ii) | correct use of $\Delta E = k\Delta T$ per particle,<br>$\Delta E = Nk\Delta T = 2.8\times10^{3}$ J; | 2 | $3/2NkT$ gives $4.2\times10^{3}$ J for (2)<br>$N = 6\times10^{24}$ gives $2.9\times10^{3}$ / $3\times10^{3}$ / $4.4\times10^{3}$ J for (2)<br>**accept** $4.9\times10^{-22}$ / $7.4\times10^{-22}$ J for (1)<br>**ignore** sign of answer |
| | (b) | (i) | any three of the following, (1) each<br>• particle energy / speed / momentum decreases;<br>• collision frequency (with surface) decreases;<br>• momentum change per collision decreases;<br>• force on surface is rate of change of momentum;<br>• pressure is (average) force per unit area; | 3 | QWC: third mark can only awarded if answer describes changes of particle properties.<br>**not** fewer collisions<br>**ignore** statements linked to rise in temperature |
| | | (ii) | use of $pV = NkT$;<br>$8.8\times10^{4}$ Pa; | 2 | accept use of $P/T$ = constant<br>$N = 6\times10^{24}$ gives $9(.2)\times10^{4}$ Pa for (2)<br>otherwise no ecf on incorrect $N$ |
| | (c) | | $\frac{2}{500} = \frac{e^{\varepsilon/k288}}{e^{\varepsilon/k253}} = e^{\frac{\varepsilon}{k}(\frac{1}{288}-\frac{1}{253})} = e^{-3.4\times10^{19}\varepsilon}$<br>$\ln(4\times10^{-3}) = -3.4\times10^{19} \times \varepsilon$, so $\varepsilon = 1.6\times10^{-19}$ J | 3 | correct substitution of all data (1)<br>method i.e. anything which eliminates $C$ (1)<br>correct evaluation - no ecf on incorrect substitution (1) |
| | | | **Total** | **12** | |

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| **12** | (a) | | $k = 360/1.3\times10^{-2} = 2.8\times10^{4}$ N m$^{-1}$ | 1 | |
| | (b) | | $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$<br>$f$ = 3.4 Hz | 2 | correct combination of $f = \frac{1}{T}$ and $T = 2\pi\sqrt{\frac{m}{k}}$ for (1)<br>evaluation (1)<br>$k = 3\times10^{4}$ gives 3.5 Hz for (2)<br>allow ecf from incorrect $k$ from (a) |
| | (c) | | any three of the following, (1) each:<br>• bumps / road vibrate spring at natural frequency (and resonance occurs);<br>• (at resonance) the frame / rider experience large amplitude oscillations;<br>• damping removes energy from the system;<br>• by converting kinetic energy into heat;<br>• reducing amplitude of oscillations; | 3 | QWC third mark can only be awarded if technical terms (such as amplitude, frequency, resonance, kinetic energy, heat) have been used correctly.<br>**not just** resonance |
| | (d) | | $A = 12.5\times10^{-3}$ m, $E = 0.5kA^2 = 2.1$ J / 2.3 J;<br>correct shape and correct phase;<br><br>**accept** evidence of gradient to measure velocity and calculate maximum KE - gives 1.6 J to 2.1 J. | 2 |  |
| | | | **Total** | **8** | |

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 13 | (a) | | $\frac{GMm}{r^2} = \frac{mv^2}{r}$;<br>cancellation / rearrangement to final formula; | 2 | **look for** cancelling down of *r* and *m* |
| | (b) | | $E = 0.5mv^2 - GMm/r$;<br>substitution for $v^2$ (and manipulation) to final formula; | 2 | **not just** $E_k = GMm/2r$ |
| | (c) | |  | 1 | anything which has *E* approaching zero more and more slowly from a negative value with increasing *r*.<br><br>ignore curve for *r* less than *R*. |
| | (d) | (i) |  <br>force on spacecraft from engine | 1 | arrow vertically down anywhere on the diagram |
| | | (ii) |  <br>velocity of gas from engine | 1 | **look for** arrow in opposite direction to force arrow of previous question. |
| | | (iii) | $-\frac{GMm}{2}\left(\frac{1}{r_f} - \frac{1}{r_i}\right)$;<br>work = (-) $2.1\times10^9$ J; | 2 | use of $-\frac{GMm}{2r}$ for (1)<br>correct evaluation (1)<br>ignore sign of final answer, **accept** $2\times10^9$ J |
| | | | **Total** | **9** | |

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